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# International Dimensions of the Productivity Paradox

*Don't blame IT!*

*Sanjeev Dewan and Kenneth L. Kraemer*

The productivity paradox of information technology questions the contributions of IT to economic output and productivity, based on the fact that there has been a marked slowdown in productivity growth despite massive and growing investments in IT. Figure 1 (top half) illustrates the paradox for the U.S., graphing the annual growth of labor productivity and new IT investment per worker over the period 1965–1994.[1] It is apparent that annual growth rate in labor productivity has slowed from over 3% in the 1960s to roughly 1% in the 1990s. By comparison, IT investments have been growing at much higher rates for most of this time period. These and other similar trends in the U.S. economy are concisely expressed by Robert Solow's now-famous quip that "the computer age is everywhere but in the productivity statistics."

In fact, Solow's observation applies equally well to other advanced economies as it does to the U.S. A slowdown in productivity growth has been the plight of other developed countries as well. The bottom half of Figure 1 displays the annual growth of labor productivity (output per worker) for the G-5 countries, the five largest economies in the world.[2] The overall trends for the five countries are similar, and in all cases labor productivity growth has slowed down to 1–2% in the 1990s, from somewhat higher levels in earlier time periods. This slowdown has

[1]Labor productivity is measured by the Bureau of Labor Statistics in terms of real output (gross domestic product—GDP) per worker, while IT is measured by Bureau of Economic Affairs asset category Office, Computing and Accounting Machinery (OCAM). This category was dominated by office equipment such as typewriters and photocopiers in the 1960s, but over time OCAM has become increasingly representative of computers and peripheral equipment. To smooth the series and clarify the underlying trends, we display 5-year moving averages for both variables.

[2]We focus on labor productivity, rather than the more appropriate multifactor productivity measure, because the latter is difficult to obtain for countries other than the U.S. In any case, both productivity measures tend to move together.

occurred concurrently with relatively much faster growth rates of IT capital per worker. Figure 2 depicts the cumulative average growth rates in IT capital stock per worker and in output per worker. In all cases, the growth rate of IT capital per worker dwarfs the growth rate of labor productivity. Indeed, all five countries look very similar in this regard.

Despite the fact the productivity paradox of IT is an international phenomenon, virtually all of the considerable debate on the subject has been restricted to the U.S. (see [1–3, 5, 8–10]). The purpose of this article is to go beyond the U.S. and examine the experience of other developed countries with respect to returns on IT investments. The hope is that by pooling the experiences of several similar countries, we can provide new insights into the payoffs from IT investment (or lack thereof) for each individual country. Before doing so, however, we briefly review the productivity paradox debate in the U.S. context. Central discussions on the paradox, and IT business value in general, have occurred in the Workshop on Information Systems and Economics (WISE) over the years. For example, the 1997 Workshop opened with a country-level analysis, followed by several firm-level analyses and a panel discussion.[3]

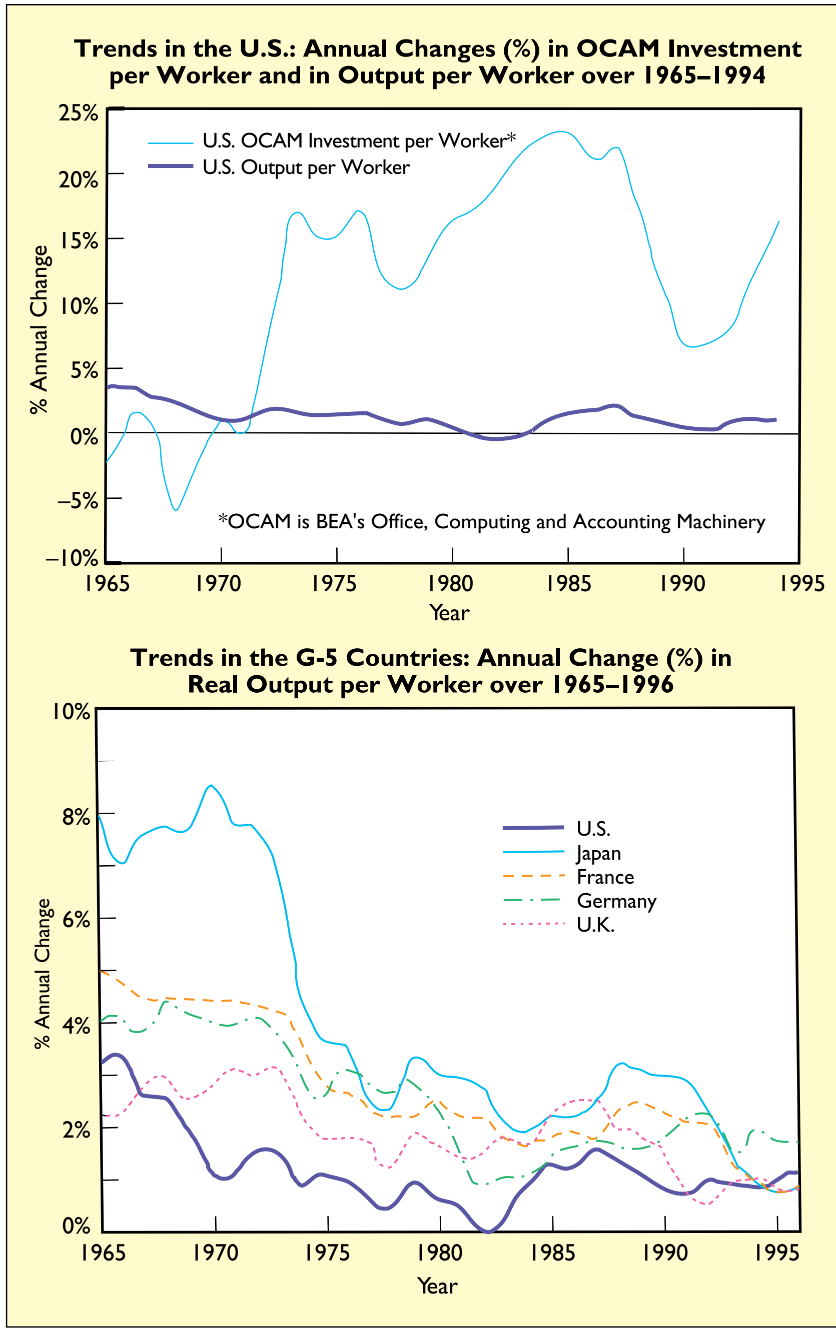


**Figure 1.** Illustrating the productivity paradox

## The Dialog in the U.S. Context

As suggested by Brynjolfsson and Hitt in this section, the U.S. experience with IT value to date can be characterized by two main periods: the productivity paradox period and the IT payoff period. In both these periods, the U.S. economy has seen an explosion in deployed computing power, driven by the continuous and dramatic price/performance improvements of IT—the quality-adjusted price of computing has declined at the average annual rate of 20% over the last three decades. The productivity paradox debate was born when the high expectations from rapid computerization failed to be reflected in the productivity statistics, and analysts such as Steven Roach and Paul Strassman took up

[3]See the WISE '97 Web site: webfoot.csom.umn.edu/faculty/kauffman/wise97/wise97prog.htm

the issue in the media. Scholars addressed the issue too, but academic studies based on aggregate U.S. data from the 1970s and 1980s failed to find evidence that IT made a measurable positive contribution to output. Beginning in the early 1990s, the pattern of research evidence shifted.

Several firm-level studies, based on production function analysis, have documented substantial positive returns from IT investment. Starting with Brynjolfsson and Hitt, analyses of different samples of Fortune 1,000 companies have estimated average gross returns on IT investments ranging from 50% to over 100%, depending on the specific model and data (see [2, 3, 5]). There is further evidence of excess returns on IT investment relative to labor and some evidence of excess returns to non-IT capital [3, 5]. In other words, shifting dollars at the margin from labor and non-IT capital inputs into IT would have led to a higher average output of U.S. firms, over the period of analysis. Finally, IT capital is a net substitute for non-IT capital and labor, suggesting that the factor share of IT in production will grow to more substantive levels over time, as IT displaces non-IT factors of production [3]. It is worth noting, however, that Sichel's [9] analysis, based on a growth accounting framework, using different assumptions than the above stream of research, leads to less "bullish" conclusions on the macroeconomic contributions of IT. Thus, there is less than complete unanimity in the research world on this issue.

**Annual Average Growth Rates of IT Capital per Worker and Output per Worker for the G-5 Countries over the Period 1985–1995**

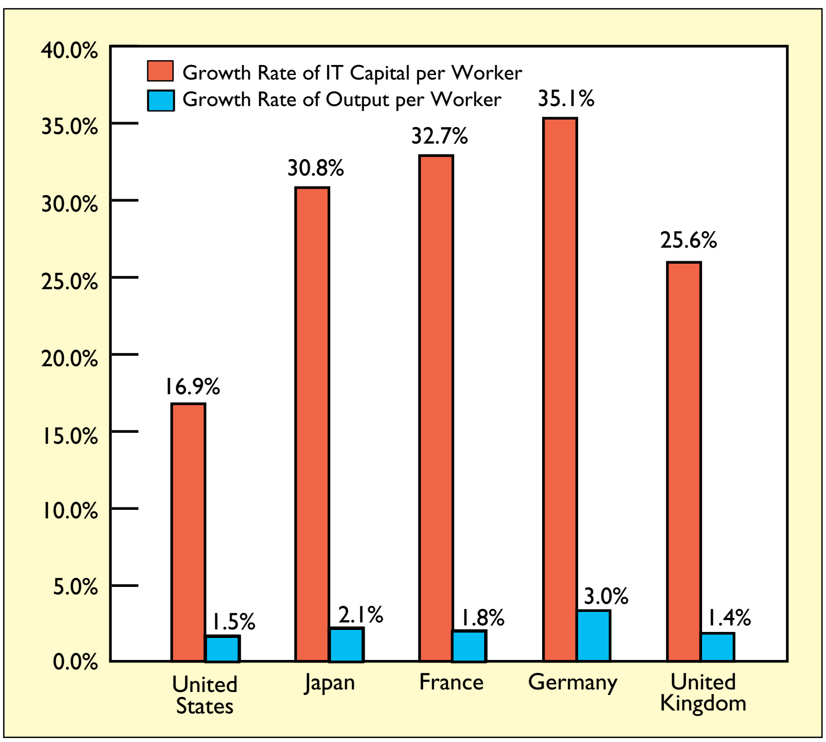


**Figure 2.** Productivity paradox of IT is an international phenomenon

Along with research attention, the productivity paradox continues to receive much coverage in the popular business press. Stephen Roach, Chief Economist at Morgan Stanley, is a leading figure who has kept the debate in the foreground, but whose views on the issue have changed several times. For example, Roach launched a crusade in the late 1980s for IT-led restructuring to boost productivity in the service sector, which is increasingly dominating the U.S. economy, but has lagged behind the manufacturing sector in productivity growth. Roach has since switched his position, as reflected in the following quote from the *New York Times* [6]: "doubts have caused me to rethink many of the glorious conclusions that I have long argued would be part of the sacred productivity-led recovery." Roach's recent doubts about the role of IT as an engine of reengineering are based on reports of negative consequences accompanying some corporate downsizings. While Roach's opinions appear to be based on simplified analysis and anecdotal evidence of industry trends, they have focused attention on the importance of scientific evidence regarding IT and productivity.

Paul Strassman, former CIO of the Xerox Corporation and the U.S. Department of Defense, has also kept the debate alive. He is skeptical about the recent positive findings by academics and prefers his own line of analysis, summarized in the following excerpt from *Computerworld* [10]: "Contrary to expectations, productivity hasn't improved during the past decade. The amount of SG&A (selling, general, and administrative expenses) required to manage every dollar's worth of COGS (cost of goods sold) hasn't fallen, despite massive IT investments." In our view, the trouble with this line of analysis is that it is based on imprecise (and possibly incorrect) measures of productivity. COGS and SG&A are both inputs to production and their ratio does not measure productivity, which ought to be a ratio of output to input. Further, IT affects both COGS and SG&A and therefore there is no reason to expect a particular trend in their ratio. The spirit of this argument is also reflected in recent organizational research [7] that examines the effects of corporate downsizing on the ratio of administrative staff to total employees.

While analyses such as those by Roach and Strassman are less than rigorous, they highlight different facets of the problem and the diversity of opinion. They also suggest, however, that perhaps additional perspectives and different types of analyses might be required to establish robustness and to make the findings more widely accepted. The analysis described here is one step in this direction.

**Table 1.** Summary statistics of key variables in 1985 and 1992 for 17 developed countries (dollar figures are in billions of 1990 U.S. dollars)*

| Variable | 1985 Mean | 1985 Std Dev | 1992 Mean | 1992 Std Dev |
|---|---|---|---|---|
| GDP ($Bn) | 665 | 1,138 | 792 | 1,332 |
| IT Stock/GDP | 0.015 | 0.008 | 0.110 | 0.031 |
| Non-IT Stock/GDP | 1.53 | 0.68 | 1.58 | 0.65 |
| Number of Workers (Millions) | 18.8 | 27.0 | 20.1 | 30.4 |
| GDP per Worker ($) | 33,704 | 4,425 | 36,864 | 4,467 |
| IT Capital per Worker ($) | 526 | 368 | 4,027 | 1,016 |
| Non-IT Capital per Worker ($) | 50,130 | 19,770 | 57,262 | 57,262 |

*The countries in the data set: United States, Canada, Switzerland, Norway, Sweden, Australia, Germany, Japan, Finland, Denmark, France, Belgium, United Kingdom, Netherlands, Austria, Italy, and New Zealand.

**Table 2.** Estimates from the cross-country production function model

| Variable | Parameter Estimate | T-Statistic |
|---|---|---|
| Change in IT Capital per Worker ($a_1$) | 0.041 | 3.538 *** |
| Change in non-IT Capital per Worker ($a_2$) | 0.056 | 0.686 |
| Change in the number of Workers ($a_3$) | –0.153 | –0.540 |
| $N$ | 17 | |
| $R^2$ | 0.73 | |

*** indicates significance at 1%

The cross-country regression model is as follows:

$$\text{Log } GDP\_WKR_{1992} - \text{Log } GDP\_WKR_{1985} = a_1(\text{Log} IT\_WKR_{1992} - \text{Log } IT\_WKR_{1985}) + a_2(\text{Log } K\_WKR_{1992} - \text{Log } K\_WKR_{1985}) + a_3(\text{Log} WKR_{1992} - \text{Log} WKR_{1985}),$$

$GDP\_WKR_t$ = GDP per Worker in Year $t$,
$IT\_WKR_t$ = IT Capital Stock per Worker in Year $t$,
$K\_WKR_t$ = Non-IT Capital Stock per Worker in Year $t$, and
$WKR_t$ = Number of Workers (total labor force) in Year $t$.

## Cross-Country Research Design

Our research method is based on pooling aggregate data on output, IT and non-IT inputs from several developed countries, to examine if IT is making a measurable contribution to the economic output of these nations [4]. We are proposing a country-level approach, in contrast to the firm-level research cited previously. The distinctive features of the country-level approach are as follows:

- It directly addresses the productivity paradox at the level of analysis at which the research has shown it to exist—the country level.
- It enables one to assess whether IT is leading to a "bigger economic pie" or merely redistributing economic gains among different industry sectors or firms in the economy.
- It involves pooling data from several similar countries, so that new insights can be gained about the IT payoff for each of those countries.
- It broadens the scope of existing firm-level research, which has focused exclusively on large U.S. corporations and, therefore, might not be representative of the experiences of the major economies in the world.

The key payoff from adopting this distinctly different perspective and level of analysis is that if the results are broadly consistent with earlier firm-level findings, then this would boost the confidence that can be placed in this entire stream of research.

We estimate returns on IT investments by pooling data from 17 developed countries over the period 1985–1992. Our estimation model, derived from the well-known Cobb-Douglas production function, relates changes in GDP per worker to changes in IT capital stock per worker and non-IT capital stock per worker. In the regression model—presented in Table 2—the dependent variable is the change in GDP per worker over the sample period 1985 to 1992, and the explanatory variables are: the change in IT capital stock per worker, the change in non-IT capital stock per worker, and the change in the number of workers itself, over the same time period. We use ordinary least squares (OLS) regression to obtain estimates of the three production function parameters $a_1$, $a_2$, and $a_3$. The values of the key parameters $a_1$ and $a_2$ are

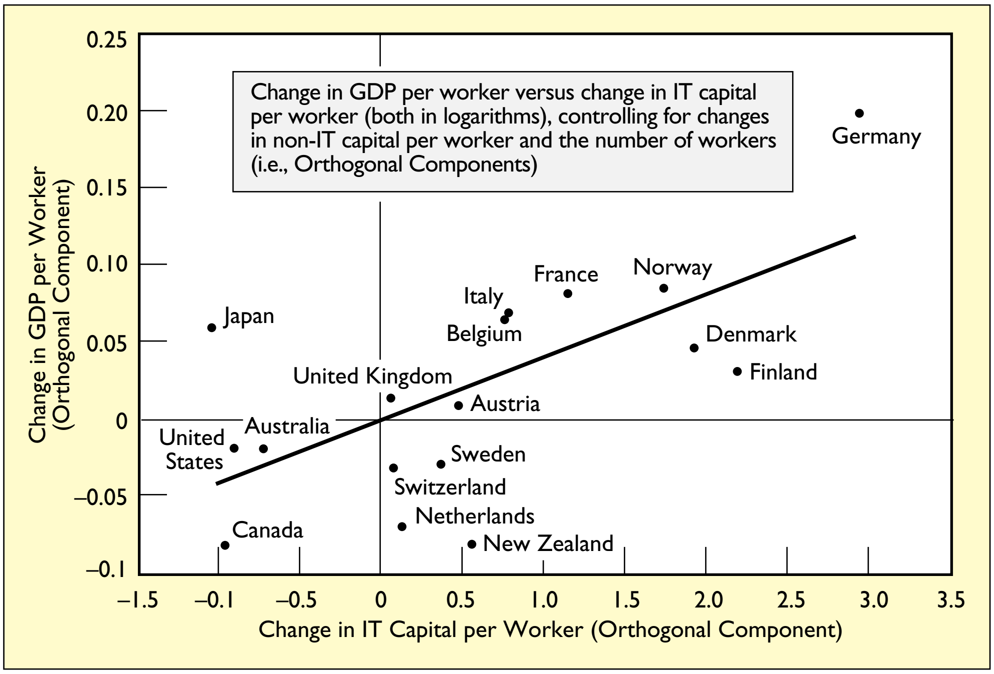


**Figure 3.** Positive relationship between change in IT capital per worker and change in GDP per worker

interpreted as the percentage change in GDP per worker associated with a 1% change in IT capital per worker and a 1% change in non-IT capital per worker, respectively. This particular specification was chosen for the following reasons:

- It is a simple linear model (in logarithms) that allows us to focus on the structure of returns on IT versus non-IT capital investment.
- Analyzing ratios of variables to the number of workers minimizes the effect of size-related biases in our econometric estimates (we effectively control for heteroskedasticity).
- Taking differences allows us to control for fixed effects that vary with country, such as the structure of the economy, number of work hours, weather, infrastructure, and technical efficiencies.
- We analyze differences between the start and end of the sample period (1985–1992) to allow for possible adjustment lags in the production system.

Next, we briefly explain the sources of our data and the construction of our variables. IT investment data were obtained from International Data Corporation (IDC), while GDP, non-IT capital and labor data were obtained from the Penn World Tables [11], the International Labor Organization (ILO), the International Monetary Foundation (IMF) and other sources. The construction of variables is described in detail elsewhere [4] and we only provide a brief summary here.

The IDC database contains investment in current U.S. dollars in four distinct IT categories: Hardware, Data Communications, Software, and Services. These investment flows are combined to calculate the net stock of IT capital in constant 1990 U.S. dollars. This measure of IT capital stock focuses on the end use of computers themselves and does not include embedded microelectronics nor telecommunications. GDP and non-IT capital stock are obtained from the 1995 version of the Penn World Tables. The distinctive feature of this widely used cross-country database is that it displays key national variables using currency conversions based on purchasing power parities, rather than exchange rates, so that real quantity comparisons can be made across countries and over time. Finally, the labor force data (number of workers) is obtained from the ILO Labor Statistics Database and IMF.

Table 1 provides the list of 17 developed countries in our data set, along with their summary statistics in 1985 and 1992. These countries are by and large the most developed and richest counties in the world, and all of them are members of the OECD. All dollar figures cited in the table are in billions of constant 1990 U.S. dollars. The average economy is quite large with an average GDP of $792 billion in 1992 and a work force of roughly 20 million workers. GDP per worker, a measure of labor productivity, increased 9.4% over the sample period, going from 33,704 in 1985 to 36,864 in 1992. What stands out in the table is the increase in IT inputs: the factor share of IT capital (IT as a percentage of GDP) increased from 1.5% in 1985 to 11% in 1992. IT capital per worker went from $526 in 1985 to $4,027 in 1992, an increase of 666%. By comparison, the factor share of non-IT capital, and non-IT capital per worker, increased by only 3.3% and 14.2%, respectively. These comparative changes in the deployment of IT and non-IT capital reflect the

**IT investments are contributing to output and productivity at a rate that is disproportionate to their factor share in production.**

relative price changes and attempts by countries to take advantage of the relatively superior price/performance improvements in IT.

## Returns from IT Investments

We start with a simple graphical illustration of the relationship between IT and output growth. Figure 3 displays a scatter plot of the "orthogonal components" of the change in GDP per worker and the change in IT per worker (both measured in logarithms), for our set of 17 developed countries. The orthogonal components are the portions of the respective variables not explained by the variation in the control variables, which are the changes in non-IT capital per worker and in the number of workers. Technically, the orthogonal components are the residuals obtained by separately regressing the change in GDP per worker and change in IT per worker against the two control variables. The trend line in Figure 3 slopes upward, implying that an increase in IT capital per worker is associated with an increase in GDP per worker, on average. Countries scattered above (below) the trend line experienced a higher (lower) than average change in output per worker, corresponding to the change in the level of their IT capital per worker.

To quantify the relationship depicted graphically in Figure 3, we turn to the estimates from our cross-country production function model, presented in Table 2. Of the three model parameters, only $a_1$ is statistically significant.[4] Its value is positive at the 1% significance level and estimated to be 0.041. This estimate suggests that a 1% increase in IT capital is associated with a 0.041% increase in output. The average factor share of IT (IT as a fraction of GDP) for the 17 countries over the sample period is 0.058. Accordingly, the average gross return implied by our IT elasticity estimate of $a_1$ is 0.041/0.058 = 70.6%. In other words, an increase in IT capital stock of \$100 million is associated with an average increase in GDP of \$70.6 million. If the return on investment seems high, note that it is gross of depreciation and interest rates, which can be as high as 25–30% for IT. Further, there is considerable imprecision in the statistical estimates of return: the 95% confidence interval ranges from 30.3% to 111%.

These estimates can be applied to U.S. data, where the IT factor share over 1985–1992 averaged about 7%. Accordingly, our estimate of gross return from IT investment for the U.S. is 0.041/0.07 = 58.6%. This estimate is well within the range of findings from U.S. firm-level research. Thus, the country-level approach we have used leads to results that are broadly consistent with previous firm-level research [2, 3, 5], increasing our level of confidence in these findings.

To summarize, our analysis suggests that developed countries are receiving a positive and significant return on their IT investments. The returns from non-IT capital investments, however, are not statistically significant at the margin.

## Interpreting the New Evidence on Returns to IT

How can we explain the comparative returns from IT and non-IT capital investment implied by our findings? A possible explanation is that developed countries have already built up a mature stock of such assets as industrial and transportation equipment, plant, inventory and structures and can therefore expect only normal or below-normal rates of return from further investment in non-IT capital. By contrast, there is ample room for productive IT investments to further take advantage of continuing improvements in IT price/performance. New IT capital investments appear to be the key for further improvements in output per worker, especially when coupled with new and complementary business models, which together yield higher rates of return.

[4] We do not believe that multicollinearity is the reason for the insignificance of the non-IT coefficients, for the following reasons: the residual plots did not indicate any abnormal behavior; perturbations to the data set, by excluding or including some countries, did not result in material changes to the estimates; none of the simple correlations among the explanatory variables are statistically significant.

One example of such new business models is offered by Dell Computer. Dell's business model, which involves direct sales and build-to-order production for specific customer segments, has been so successful that in the 1990s, it is now being adopted by every major PC company in the industry. Dell uses IT to support its business model and to coordinate with suppliers and customers through real-time sharing of information, thereby achieving efficiency and virtual integration throughout its value chain. Dell's revenues have grown at an average annual rate of 55% over the last five years, even though its ratio of administrative staff to total employees has remained unchanged, and its stock price growth has outpaced all firms in the industry by an order of magnitude.

Another example of a new business model (at the country level) is offered by the city-state of Singapore. Since 1980, Singapore has promoted itself as a business hub for multinational corporations and systematically invested in IT use by business and government. It has also invested heavily in education of IT professionals, construction of industry IT networks and promotion related to IT use. As a consequence, Singapore has become *the* business hub for the Asia-Pacific region attracting high value added production and business services. Wong Poh Kam's [12] study of IT investments in Singapore estimated the return on investment at 88%, which is significantly higher than the assumed capital depreciation plus interest rate of 37%.

How can we explain these high returns from IT investment in developed countries? A potential explanation is that the estimated returns from IT investment reflect other changes in the economies of developed countries that are complementary to IT investments, such as infrastructure, human capital, and informatization of business processes. In other words, the positive returns are not only due to increases in IT capital per worker, but also reflect simultaneous changes in education, infrastructure and other factors that complement labor and make it more productive. The developed countries have learned how to use the technology effectively over the past 30 years; part of the cost of their IT investments can usefully be thought of as the tuition paid for that learning.

What does all this add up to with respect to the productivity paradox of IT? Figures 1 and 2, which illustrate the paradox, suggest that the slowdown in productivity growth is puzzling given the level and growth of IT investments. While the slowdown is potentially explained by several different factors (for example, the overstatement of inflation), our results clearly indicate that IT is not to be blamed for the slowdown. On the contrary, IT investments are contributing to output and productivity at a rate that is disproportionate to their factor share in production. For the countries in our sample, IT capital constitutes 1/20 of GDP, but accounts for one-third to one-half of growth in output (and productivity). As IT continues to displace labor, factory, and equipment throughout the production system (from suppliers to producers to customers), its share of the total inputs to the economy will continue to increase. As this occurs, and IT investments approach 10–15% of GDP, the economic contributions of IT will be more visible and the productivity issue will no longer be a matter of debate. C

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